THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

DECEMBER, 1956

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Impact-Testing Symposium

AMER. SOC. TESTING MATERIALS: 'Symposium on Impact Testing.' *Special Tech. Publn.* No. 176, published 1956; 170 pp.

Based on Symposium on Impact Testing held at the 58th Annual Meeting of the Society, June 1955.

Introduction, p. 1.

Note on previous impact-testing symposia and on the widening of the field for the 1955 review, to cover shock testing as well as conventional impact testing.

S. L. HOYT: 'Notched-Bar Testing: Theory and Practice', pp. 3–6; disc., pp. 7–9.

This paper covers 'a few of the points thought to be especially significant in handling the practical phases of brittle fracture'.

Attention is directed to the increased realization, during recent years, of the significance of notch effects and of the nature of notch brittleness and stress-raising factors. It is emphasized that the service problem is the brittle behaviour and low energy-absorbing capacity of ductile steel: the problem of ductile failure under notch conditions is much more complex, less well understood, and seldom encountered in practice. On the basis of this introduction, the author considers the application of fundamental concepts to the selection of steels and to the rating of steels for notch toughness.

C. E. HARTBOWER: 'Transition Behaviour in V-Notch Charpy Slow-Bend Tests', pp. 10–22; disc., pp. 23–4.

Tests are reported on three structural steels representative of the full range of commercial deoxidation practice, and on carbon-manganese steels of varying composition.

It is shown that slow-bend tests provide a measure of the temperature, the fibrosity and the deformation associated with brittle fracture (formation of a self-propagating crack).

T. N. ARMSTRONG and O. O. MILLER: 'Effects of Manganese and Aluminum Contents on Transition Temperature of Normalized Nickel Steel', pp. 25–39.

It has been fairly well established that in normalized carbon steels of moderate-to-low carbon content fine ferrite grain size is conducive to low temperature of transition from ductile to brittle behaviour. The generally accepted method of producing fine-grained steels is to add aluminium after preliminary deoxidation with silicon: a residual or acid-soluble aluminium content of 0·015 per cent. is usually sufficient to ensure fine austenite grains at the temperatures associated with normalizing, and fine ferrite grains after air-cooling. There is, however, evidence indicating that the minimum aluminium content required to obtain fine grain size may not necessarily be optimum from the point of view of low transition temperature.

The transition temperature of mild carbon steel may be lowered also by increasing the manganese content, and it has long been recognized that nickel is one of the most effective means of lowering the temperature of brittle fracture.

The work reported in this paper was planned to determine: (1) whether the effects of manganese and nickel are additive, (2) whether the optimum aluminium content for lowering the transition temperature of carbon steels is independent of the manganese content, and (3) whether the optimum aluminium addition is the same for nickel steel as for carbon steel.

The study was made on 24 heats of steel, half of which contained no nickel and the other half 2¼ per cent. of nickel. Each of these types was produced at three manganese levels (0·4, 0·95 and 1·5 per cent.), and each of the six combinations was made at four levels of acid-soluble aluminium. Carbon was kept constant in all the melts at 0·15±0·01 per cent.

The results of tests on these steels led to the following conclusions:—

'1. Deoxidation with silicon plus sufficient aluminium to obtain 0·03 to 0·09 per cent. acid-soluble aluminium in the steel, in place of silicon alone, lowers the transition temperature of normalized 0·15 per cent. carbon steel by 70F°. (40C°.) on the average.

'2. There is believed to be no significant difference in transition temperature among acid-soluble aluminium contents of 0·030, 0·055 and 0·090 per cent., although the lowest transition temperature was obtained in the nickel steels of each of the higher-manganese series with an aluminium content of 0·030 per cent. The minimum aluminium content for ensuring low transition temperature in silicon-killed 0·15 per cent. carbon steels was not determined in this work, but published data indicate that it may be as low as 0·015 per cent.

'3. Manganese significantly lowers the transition temperature of normalized 0·15 per cent. carbon plain carbon steels. The average magnitude of this effect, based on data at 0·4, 0·95 and 1·5, per cent. manganese, is to lower the transition temperature by 84F°. (47C°.) for each 1 per cent. of manganese. The effect is more pronounced with increase in manganese within the range 0·4 to 0·95 per cent. than within the high range of 0·95 to 1·5 per cent. manganese.

'4. Nickel effectively lowers the transition temperature of normalized carbon steel. The average

magnitude of this effect, based on data at 0 and 2·25 per cent. nickel at the two levels of manganese (0·4 and 0·95 per cent.) and the four levels of aluminium, is to lower the transition temperature 46F°. (26C°.) for each 1 per cent. of nickel. The principal advantage in nickel over manganese, although not shown in these data, is that the transition temperature of low-carbon steels is progressively lowered with increase in nickel content, whereas there appears to be a limit on the percentage of manganese that may be beneficial.

'5. In the presence of 2·25 per cent. nickel, an increase in manganese content from 0·4 to 0·95 per cent. has no significant effect on transition temperature: both rise and fall were found.

'6. The combination of 2·25 per cent. nickel and 1·5 per cent. manganese consistently produced 10–15 per cent. martensite in the normalized, ¾-in., 0·15 per cent. carbon-steel bars used, which raised the transition temperature appreciably.

'7. The tempering of normalized 0·15 per cent. carbon steel produces no significant change in its transition temperature, as determined by the Charpy keyhole-notch test, if the microstructure is pearlite + ferrite. If sufficient martensite is present in the normalized condition to contribute brittleness, such as occurred in the 1·5 per cent. manganese–2·25 per cent. nickel steels, tempering significantly lowers the transition temperature.

'8. A decrease in both austenite and ferrite grain size is associated with lower transition temperature. The grain size of the ferrite appears to have more influence on transition temperature than the prior austenite grain size.'

The authors emphasize that this investigation was carried on specimens taken from ¾-in. bars rolled from steels made in a small induction furnace, operated under closely controlled conditions. The numerical values obtained might well vary from results of similar tests made on specimens taken from large plates of commercial steels, but it is believed that the relative effects of the variables studied are generally applicable.

T. N. ARMSTRONG and W. L. WARNER: 'Low-Temperature Transition of Normalized Carbon-Manganese Steels', pp. 40–58.

Report on investigations made to determine the energy-temperature relations for a number of carbon-manganese steels: the work was one phase of a study of the effects of welding on transition temperature.

The following are the main conclusions:—

1. Increase in carbon content up to about 0·20 per cent. carbon does not very greatly affect the ductility transition (temperature at which 15 ft.-lb. is obtained).

2. Increase in carbon up to 0·45 per cent. raises the fracture-transition temperature of normalized carbon-manganese steels. The amount the transition temperature is raised by increase in carbon depends somewhat upon the manganese content of the steel.

3. Increase in manganese content within the range 0·45–1·00 per cent. decreases the ductility-transition temperature of normalized carbon-manganese steels.

4. Increase in manganese content within the range 0·45–1·00 per cent. lowers the fracture-transition temperature of carbon-manganese steels. The magnitude of the decrease depends somewhat upon the carbon content of the steel.

5. Both the fracture-transition temperatures and the ductility-transition temperatures are lower for the experimental steels examined than values which have been reported for commercial steel plates of comparable compositions. It is believed, however, that the general effect of carbon and of manganese would be relatively the same in normalized commercial steel plates.

R. S. ZENO: 'Effect of Specimen Width on the Notched-Bar Impact Properties of Quenched-and-Tempered and Normalized Steels', pp. 59–69.

To provide further guidance for design engineers using small-scale test results in the design of large structures, an investigation was made of the effect of specimen geometry on the V-notch Charpy impact properties of oil-quenched and tempered nickel-chromium-molybdenum steel (3 per cent. nickel, 1 per cent. chromium, 0·1 per cent. molybdenum), and of normalized 0·2 per cent. carbon steel.

A size effect was exhibited in the transition temperature for both steels. Energy, appearance of fracture and deformation transition temperatures were lowered as the width of the specimen was decreased. Energy per unit fracture area and volume decreased with increasing width of specimen for the nickel-alloy steel, for all temperatures of test except −110°C. (−166°F.). For the carbon steel energy per unit fracture area and volume increased above the highest energy-transition temperature and decreased below this transition temperature as the width of the specimen was increased. Energy per unit fracture area and volume is a function not only of specimen geometry, but also of microstructure and transition temperature.

D. E. DRISCOLL: 'Reproducibility of Charpy Impact Test', pp. 70–4; disc., p. 75.

In view of widespread doubts as to the reproducibility of the Charpy impact test, and hence its suitability as an acceptance test, work has been carried out at Watertown Arsenal Laboratory to determine the validity of the method. The work was done on homogenized steels within the following range of composition:—carbon 0·37–0·385, silicon 0·27–0·28, manganese 0·75–0·77, sulphur 0·013–0·015, phosphorus 0·013–0·016, nickel 1·73–1·77, chromium 0·83–0·86, molybdenum 0·25–0·27, per cent. The steels were heat-treated to three energy levels. The programme provided for investigation of variables which might contribute to inconsistency of results e.g., condition of the impact machine, methods of machining and finishing the specimen, and techniques of cooling and testing the specimens. The results obtained are considered to justify the following conclusions:—

In general, the wide scatter in energy values which has been reported from various sources is due to poor quality of steels and/or poor heat-treatment.

Variations in machines are caused by poor testing techniques, and/or the poor condition of the Charpy machine. As a result of the surveys reported, the Watertown Arsenal Laboratory and many private laboratories concur in the opinion that, when properly conducted, the Charpy test is truly accurate and reproducible. Part of the specimens prepared in connexion with these tests are being used to check other Charpy impact machines in the U.S.A., to determine the causes of variations which have been encountered.

T. S. DESISTO: 'Automatic Impact Testing from Room Temperature to −236°C.', pp. 76–83.

This paper also deals with work done at Watertown Arsenal Laboratory. It describes equipment for conducting impact tests automatically from room temperature to −236°C. Results of tests on A.I.S.I. 4340 nickel-chromium-molybdenum steel and a titanium-base alloy containing aluminium and vanadium are reported. It is noted that the titanium alloy showed a high degree of toughness at −236°C.

J. I. BLUHM: 'The Influence of Pendulum Flexibilities on Impact Energy Measurements', pp. 84–92; disc., p. 93.

It is shown that discrepancies which have been noted in the measurement of energy absorption from one Charpy impact machine to another may be attributable, at least in part, to the flexibility of the machine, and that such flexibilities may give rise to differential behaviour of high- and low-strength specimens which have identical toughness.

G. GERARD: 'The Impact Tube: A New Experimental Technique for Applying Impulse Loads', pp. 94–109; disc., p. 110.

The paper deals with a new experimental technique for applying loads of an impulsive nature to diaphragms or plates of various shapes. Some data are given on an aluminium alloy, an annealed 18–8 chromium-nickel steel and an annealed low-carbon steel.

W. RAMBERG and L. K. IRWIN: 'Longitudinal Impact Tests of Long Bars with a Slingshot Machine', pp. 111–24; disc., p. 125.

The history of longitudinal impact testing is traced from the early 1800's to the present day, to demonstrate its importance in a study of the dynamic strength of materials, and to indicate some of the difficulties encountered in interpretation of results of impact tests. A slingshot machine developed at the National Bureau of Standards for making impact tests is described, and some results obtained by it on high-strength steel and copper are reported.

F. H. SCHIEFER, J. C. SMITH, F. L. MCCRACKIN and W. K. STONE: 'Stress-Strain Relationships in Yarns Subjected to Rapid Impact Loading', pp. 126–40.

W. H. CROSS and M. MCWHIRTER: 'Shock Tester for Shipping Containers', pp. 141–8.

The object of this investigation was to develop a method of testing shipping containers for the longitudinal shocks encountered during railroad switching operations.

R. W. HAGER: 'Shock Testing with the Rocket-Powered Pendulum', pp. 149–55.

To meet the need for adequate testing of full-scale aircraft and ordnance structures and components, a rocket-powered pendulum has been developed which is capable of simulating certain operational shock loadings on prototype structures and components.

D. WATSTEIN: 'Properties of Concrete at High Rates of Loading', pp. 156–69; disc., p. 170.

Electrolytic and Chemical Polishing of Metals

P. A. JACQUET*: 'Electrolytic and Chemical Polishing.' *Metallurgical Reviews*, 1956, vol. 1, pp. 157–238.

This monograph, prepared by a metallurgist who has for many years carried out continuous research on this subject, deals with problems relating to methods of electrolytic and chemical polishing: the scientific and technical applications of such procedures are not included in the survey.

The subject is treated in three sections, with appendices. The first part deals with the definition of the state of a metallic surface; the second opens with a brief history of electrolytic and chemical polishing and subsequently deals with the principles underlying such treatment: in the third part the characteristics of surfaces mechanically, anodically, and chemically polished are compared.

The review includes a large number of illustrations showing apparatus used in electrolytic polishing, and the characteristics of electrolytically polished surfaces.

The appendices contain comprehensive tables giving: (1) information on solutions and operating conditions for electrolytically polishing the various metallic materials to which this technique has been applied, and (2) details of conditions suitable for chemical polishing without the use of current. The polishing of nickel and nickel alloys is dealt with in both appendices.

Thermal Cutting of Nickel-containing Materials

E. H. ROPER: 'Thermal Cutting of Aluminium, Stainless Steels and High-Nickel Alloys.'
Welding Jnl., 1956, vol. 35, Sept., pp. 915-19.

The article describes a process developed by Air Reduction Sales Company, U.S.A.

It employs standard gas-shielded metal-arc welding apparatus and the claim is made that development has reached a stage permitting satisfactory cutting of many materials which are so resistant to oxygen-cutting that mechanical means are usually employed for severing them. The new process, fully described in this article, is capable of both manual and mechanical operation: the cut surfaces are claimed to be in many cases suitable for further processing, e.g., by welding.

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* Translated by H. W. L. Phillips.

The method employs apparatus which is likely to be easily available in any well-equipped plant fabricating non-ferrous materials, and the technique would be easily learned by operators already trained in gas-shielded-arc welding or oxygen cutting.

Typical operating conditions are given for various materials, including nickel-chromium stainless steel, Monel and nickel.

NICKEL

Hexagonal Structure in Nickel

J.-J. TRILLAT, L. TERTIAN and N. TERAO: 'The Transformation of Cubic Nickel into Hexagonal Nickel.'
Comptes Rendus, 1956, vol. 243, Aug. 13, pp. 666–8.

The authors report that by bombarding a thin film of cubic nickel with ions of the order of 12 kV they produced rapid transformation to a hexagonal structure. The transformed metal, when heated in vacuo, reverted to the normal cubic structure. The kinetics of the transformation processes were traced by electron-diffraction methods, which were also used to study effects produced by oxidation of the re-transformed nickel under reduced pressure.

Nickel and Nickel Alloys: Literature Review

R. M. FULLER: 'Nickel, including High-Nickel Alloys.'
Industrial and Engineering Chemistry, 1956, vol. 48, Sept., Part II, pp. 1742–59.

The annual review issued in this journal includes a summary of the literature on nickel and nickel alloys which became available in 1955, together with some earlier items which had not been included in previous reviews. The scope covered is the alloys containing more than 40 per cent. of nickel or substantial quantities of cobalt. The six sections of the review cover, respectively:

Mining, Production and Availability of Nickel
Physical Metallurgy, Research and Development
Production, Welding and Fabrication of Nickel and High-Nickel Alloys
Materials for High-Temperature Application
Nickel Plating
Applications of Nickel and High-Nickel Alloys.

The supporting *bibliography* (classified in accordance with the text) numbers 325 items.

Low-Temperature Properties of Nickel

See abstract on p. 211.

Theoretical Weights of Nickel-base Alloys

See abstract on p. 211.

Heat of Adsorption of Oxygen on Nickel

O. D. GONZALEZ and C. PARRAVANO: 'Heats of Adsorption of Oxygen on Nickel, Platinum and Silver.'
Jnl. Amer. Chemical Soc., 1956, vol. 78, Sept., pp. 4533–7.

The adsorption thermodynamics of oxygen were studied on powdered nickel, platinum and silver specimens, in the temperature range 150°–300°C. and with surface coverages of 10^{-4} to 10^{-3}.

Gas-Permeability of Nickel

See abstract on p. 208.

Resistance of Nickel to Mercury

See abstract on p. 219.

Electrolytic and Chemical Polishing of Metals

See abstract on p. 204.

Nickel-Oxide Electrodes

E. JONES and W. F. K. WYNNE-JONES: 'The Nickel-Oxide Electrode: Part 2.'
Trans. Faraday Soc., 1956, vol. 52, Sept., pp. 1260–72.

Continuation of the report of the authors' work on the behaviour of nickel-oxide electrodes prepared by various methods. Details of Part 1 *ibid.*, 1955, vol. 51, pp. 1433–42: *Nickel Bulletin*, 1956, vol. 29, Nos. 1–2, p. 7.

In this further report particular attention is given to the electrochemical and analytical aspects of the work. Potential-against-time and potential-against-composition curves are discussed, for conditions existing both on open circuit and during the passage of current. Methods for chemical analysis of the oxide layers are described, and it is shown that the existence of variations in composition within the oxide layer may explain many features of the electrode phenomena.

Nickel-Cadmium Batteries in Pocket Torches

'Long-Life Electric Pocket Torch.'
Financial Times, 1956, Oct. 2, p. 9.

An outstanding feature of a new type of electric pocket torch recently placed on the market is that its batteries can be regenerated by plugging it into the normal domestic electricity supply. In the torch is incorporated a charging circuit which can be operated from a 220–230 A.C. supply, and the batteries can be re-charged by plugging the torch into a five-amp. two-pin socket. The pins for inserting it into the socket form an integral part of the torch and are concealed by the end cap, which also houses a spare bulb.

The new torch, which weighs about 4 oz. and is less than 5 in. long., is to be known as the 'Accu Lux'. It has a plastic oval-shaped body, fitted with a magnifying lens, bulb and switch. It is operated by two very small nickel-cadmium batteries, stated to be of new design and capable of continuous charge and discharge. It is claimed that they should not require attention for several years.

Sintered Nickel Plates for Batteries

E. J. CASEY, P. L. BOURGAULT and P. E. LAKE: 'Nickel-Cadmium Batteries: I. Sintered Plates from a New Canadian Nickel Powder.'
Canad. Jnl. Technology, 1956, vol. 34, May, pp. 95–103.

The conventional nickel-cadmium battery, invented

in Sweden about 1900, has since been used widely in Europe for various industrial applications, and porous plates of sintered nickel, to contain the electrically active material, were introduced in Germany about 1935. These plates, made by sintering fine irregular carbonyl-nickel powder at about 1650°F. (900°C.), consist of 80 per cent. free volume, and into the pores are inserted the active materials, nickel hydroxide to form positives and cadmium hydroxide for the negatives. In the past twenty years evidence has accumulated that this type of construction is versatile, dependable and rugged.

The properties required in the nickel powder to be used for battery plates have been found to be characteristic of carbonyl-nickel powder, the composition and physical form of which are especially suitable for this purpose.

The present paper describes experiments carried out by the Defence Research Chemical Laboratories, Ottawa, to ascertain the possibility of using, for the battery plates, nickel powder prepared by methods other than the carbonyl procedure. A new material tested in comparison with carbonyl nickel powder was 'seed' nickel powder made by catalytic hydrogenation of an aqueous nickel-ion solution (the process used by Sherritt Gordon Mines, Ltd.). An account is given of the composition, apparent density, and particle size of this powder, and of the tests made to establish optimum conditions of sintering and impregnation. Tests for evaluating the quality of the plates are also described.

The results indicate that sintered plates of high porosity and good mechanical strength can be prepared from the new type of powder. Such plates, when impregnated and subjected to electrolytic oxidations and reductions in a test cell, gave electrical capacities, at low rates of discharge, equal to those of plates produced commercially from carbonyl-nickel powder. At extremely high rates of discharge the new plates gave 15–20 per cent. less capacity than the commercial carbonyl-nickel plates.

Further studies on the effects of particle shape and particle-size distribution are in hand. In discussing shape of particles, electron micrographs are shown illustrating the characteristic forms of the two types of powder compared.

Nickel Catalysts in Hydrogenation Processes: Literature Review

M. R. ARNOLD: 'Hydrogenation and Hydrogenolysis.'
Industrial and Engineering Chemistry, 1956, vol. 48, Sept., Part II, pp. 1629–42.

Review of the literature on hydrogenation processes and studies which became available in 1955. This covers the hydrogenation of carbon oxides, oxo synthesis, ammonia synthesis, oil and fat hydrogenation, hydrogenation of acetylenes and other unsaturated hydrocarbons, hydrogenation of petroleum, coal, and related materials, hydrogenation of organic compounds, and fundamental studies on hydrogenation catalysts.

For the convenience of readers interested in individual aspects of the subject, the review is arranged in tabular form giving breakdowns according to the processes to which reference is made, and the types of catalyst used. Extensive reference is made to the use of nickel-containing catalysts of various types. The classified *bibliography* supporting the review contains nearly 350 items.

Raney Nickel Catalysts

W. A. BONNER and J. A. ZDERIC: 'The Stereochemistry of Raney Nickel Action. VII. Catalytic Hydrogen-Deuterium Exchange in the 2-Phenylpropionamide Series.'
Jnl. Amer. Chemical Soc., 1956, vol. 78, Sept. 5, pp. 4369–71.

The relative rates of racemization and hydrogen-deuterium exchange when (+)-2-phenylpropionamide is treated with deuterated Raney nickel in refluxing deutero-ethanol were investigated.

Nickel Coinage

E. F. FEELY: 'A Century of Nickel Coinage.'
Numismatist, 1956, vol. 69, Mar., pp. 269–73.

A historical and statistical résumé of nickel and nickel-alloy coinage in various countries, from 1850 onwards to the date of the peak consumption of nickel for this purpose, in 1947.

Analysis of Nickel-base Alloys for Thermionic Cathodes

E. K. JAYCOX and B. E. PRESCOTT: 'Spectrochemical Analysis of Thermionic Cathode Nickel Alloys by a Graphite-to-Metal Arcing Technique.'
Analytical Chemistry, 1956, vol. 28, Oct., pp. 1544–7.

In nickel-alloy thermionic cathodes, ease of activation, the ultimate degree of thermionic activity, and the emission life are markedly dependent on the nature and amount of the trace elements present in the nickel base to which the alkaline-earth emitter is applied. Trace constituents, particularly magnesium, silicon, aluminium and titanium, react with the alkaline-earth compounds (barium, strontium and calcium oxides) in the coating, to produce free alkaline-earth metals, believed to be essential for high thermionic activity. Other elements, such as iron and manganese, may react disadvantageously, to oxidize the free alkaline-earth metals. Accurate estimation of the concentration of all relevant constituents is therefore of considerable importance, and work has been in progress for many years, in the Bell Telephone Laboratories, to devise chemical and spectrochemical methods for determination of impurities in nickel. Spectrochemical methods have obvious advantages, and procedures of this type developed in the Bell laboratories were adopted in 1953 by the American Society for Testing Materials, as a Suggested Method (SM5-1). That procedure, which involves converting the metal to nickel oxide, mixing with graphite powder, and exciting in the direct current arc, has received wide acceptance by spectroscopists in the vacuum-tube industry, but it was recognized, by its originators, that it had certain inherent disadvantages, among which are the long

time involved in preparation of the samples, and certain elaborate precautions necessary to avoid contamination.

The technique described in the present paper is an improved method. In this procedure 10 mg. of nickel metal is placed in the crater of a graphite cup and burned to extinction in the direct current arc. The method provides for estimation of aluminium, cobalt, chromium, copper, iron, magnesium, manganese, silicon and titanium, in the concentration range usually of interest in this type of material, *viz.*, 0·003–0·2 per cent. of each element. The precision obtained is adequate, and the time required for analysis is considerably shorter than that involved in using the dry-oxide-powder technique.

Estimation of Nickel and Copper, using Chromatographic Methods

I. I. M. ELBEIH: 'Microgram Estimation of Copper and Nickel by EDTA Titration after Paper Chromatographic Separation.'
Chemist Analyst, 1956, vol. 45, Sept., pp. 75–7.

In principle, the procedure described involves location of individual spots of copper and nickel on a paper chromatogram of the unknown, by comparison with the position of the sulphide stains of the same metals on a parallel chromatogram run with a known solution. The copper and nickel spots are then separated and individually titrated with a standard solution of EDTA.

Spectrophotometric Determination of Aluminium in Nickel

See abstract on p. 212.

ELECTRODEPOSITION AND OTHER COATING METHODS

Levelling of Nickel Electrodeposits

D. G. FOULKE: 'Levelling Nickel.'
Metal Finishing, 1956, vol. 54, Oct., pp. 52-6.

The writer reviews the important developments which have recently taken place in obtaining 'levelling' or 'smoothing' of the basis metal in electrodeposition. He discusses the mechanism of levelling, and shows photomicrographs illustrating the smoothing obtained with a nickel-plating solution embodying an acetylenic addition agent, which has been developed by the Hanson-Van Winkle-Munning Company. The solution is of a relatively high chloride content (e.g., of the order of 12–15 oz./gal.), and the bath is operated at a high temperature, with air agitation. Anode current density is preferably maintained below 25 amp./sq. ft. Under correct conditions, stress in the deposit can be maintained at a low tensile level, or can even be made compressive.

The author discusses the influence of plating variables on the levelling obtained from the new bath, basing his conclusions on experiments in the Hanson-Van Winkle-Munning laboratories.

It has been found that:—

Increase in current density results in a slower rate of levelling

Increase in pH increases levelling

Rise in temperature improves levelling, although some divergent results have been obtained, indicating that the effect of temperature may be somewhat complex

Agitation has somewhat the same effect as a rise in the concentration of the addition agent, by virtue of promoting rapid transport into the cathode film. When the acetylenic addition agent was present in high concentration stirring made no difference to the levelling obtained

Increase in levelling resulting from increased cathode polarization was confirmed in these tests.

The above conclusions are in broad agreement with observations made by Leidheiser (*Zeitsch. Elektrochemie*, 1955, vol. 59, p. 756), and by others who have studied levelling in electrodeposits.

At the close of the paper brief reference is made to the possible use of duplex coatings. It is concluded that if levelling can be effected in a bath which yields fully-bright deposits there is no case for duplex coatings, but that if the bright and semi-bright baths are completely compatible and adhesion of the second layer to the first is good, there may be some purpose in considering such a cycle. One of the best reasons for the use of duplex coatings would be evidence of improved corrosion-resistance, and in this connexion it is recorded that preliminary studies in the author's laboratory have indicated that a 1-mil coating consisting of 80 per cent. of semi-bright nickel followed by 20 per cent. of bright nickel may perhaps be equal, from the point of view of corrosion-resistance, to 1·2 mils of bright or semi-bright nickel.

Effects of Chromium and Lead in Nickel-Plating Solutions

D. T. EWING *et al.*: 'Effect of Impurities and Purification of Electroplating Solutions; 1. Nickel Solutions; 7. The Effects and Removal of Chromium; 8. The Effects and Removal of Lead.'

Reprints, issued by INTERNATIONAL NICKEL CO., INC., of papers presented to the American Electroplaters' Society.

Originally published, respectively, in *Plating* 1953, vol. 40, Dec., pp. 1391-400 and 1954, vol. 41, June, p. 666; abstracts in *Nickel Bulletin*, 1954, vol. 27, No. 2, pp. 22–3 and Nos. 7–8, p. 129.

Electrodeposition of Nickel and Nickel Alloys: Literature Review

See abstract on p. 205.

Heating of Nickel-Plating Solutions

D. W. TAYLOR: 'Some Notes on Bi-Polarity of Nickel Heating Coils.'
Metal Finishing Jnl., 1956, vol. 2, Aug., pp. 295–6, 298.

Heating of nickel-plating solutions may be effected,

using steam or high-pressure hot water, by one of three methods:—

(1) A coil of pure nickel tube immersed in the nickel solution.

(2) A coil of pure nickel tube covered with a suitable insulating material, and immersed in the nickel solution.

(3) A heat exchanger external to the plating vat, made from a material inert to the chemical action of the nickel solution.

Method (1) is extensively used. The form of installation necessary in large vats, embodying two or more coils, sometimes results in the setting-up of a current which flows between the anodes and one section of the heating coil, and from another part of the coil to the cathode, viâ the work being plated. In such cases the section of the heating coil into which the current can be taken when entering from the anodes will assume a relative cathodic potential, while the other section of the coil, where the current is leaving the coil for the cathode, will assume a relative anodic potential. This condition is known as bi-polarity.

Methods of preventing such effects are described, with illustrations of modifications in equipment required to ensure correction. Experience with the third method of heating has so far shown it to be free from dangers of bi-polarity, but whilst the heat exchanger has this advantage, on some small vats it is more expensive to install than a heating coil.

Gas-Permeability of Electrodeposited Nickel

D. T. EWING, J. M. TOBIN and D. G. FOULKE: 'Permeation of Gases through Nickel Deposits. I. Determination of the Intrinsic Permeability of Nickel Deposits to Gases.'

Jnl. Electrochemical Soc., 1956, vol. 103, Oct., pp. 545–8.

Nickel electrodeposits subject to corrosive conditions may become perforated to the base metal at certain discrete points. Although various theories have been advanced to explain such failures, and a number of tests have been devised to measure either the tendency of nickel deposits to fail or their porosity, the nature of failure in protective nickel coatings is not yet fully understood.

Thon *et al.*, working under the auspices of the American Electroplaters' Society, discovered a structural porosity or gas-permeability characteristic of nickel deposits based on the fact that when a difference in pressure is established across a detached deposit, gas atoms or molecules flow through the 'pores' or 'capillaries' which extend through the deposit. These investigators experienced difficulty in obtaining reproducible results by this method, and attempted to develop other procedures, such as the passage of light rays or low-energy particles, for measurement of the porosity of nickel deposits. The procedure used by the authors of the present paper is, however, a modified form of the Thon gas-permeability method, and by improvements in technique and very close control of specimens they obtained reproducible results. Values were obtained for permeability constants of nickel electrodeposits to hydrogen and helium, the values for 0·0001-in. deposits being of the order of 9 and 6×10^{-8}, respectively. The experiments were made on six groups of specimens prepared by electrodepositing nickel from a Watts bath onto a passive buffed nickel base metal, from which they were readily detached. The deposits ranged in thickness from 0·00005-in. to 0·0005-in. (To check any possible influence of the basis metal, tests were made also on nickel electrodeposited on stainless steel. The resulting values were almost identical with those obtained for deposits made from the same bath on a buffed nickel base.)

Pores present in sound nickel electrodeposits are extremely small, and flow occurs by molecular streaming, probably at grain boundaries. Rolled nickel of about the same thickness as the electrodeposits studied had been reported to be impermeable to air, and this was confirmed on a 0·0001-in. thick rolled nickel sample on which no measurable gas flow could be noted for nitrogen, hydrogen or helium.

Bright Anodized Aluminium *vs.* Nickel/Chromium Plating

'Bright Anodized Aluminium *vs.* Nickel/Chromium Plating.'

Metal Finishing Jnl., 1956, vol. 2, Oct., pp. 357–63, 389.

At a recent meeting of the London Branch of the Institute of Metal Finishing, a lively debate took place on the motion that 'this meeting is of the opinion that bright anodized aluminium will rapidly replace nickel and chromium plating.'

In proposing the motion, I. WALKER urged the advantages of bright anodized aluminium, in comparison with nickel/chromium plating, on the basis of (1) its high reflectivity and good appearance, which are well retained in service, (2) its good resistance to abrasion (superior to that of the average paint film on a car), (3) the ease with which the anodized film can be produced, (4) the lower cost of applying the finish to the material, and (5) the steady availability of aluminium.

H. C. CASTELL, opposing the motion, drew attention to the following points:—

Nickel and chromium plating could be applied to all constructional metals, in combined structural and decorative applications, whereas the low strength of super-purity aluminium precluded its use for such purposes. A large amount of nickel/chromium plating is applied to zinc-base die-castings, which in turn serve a field where, for technical reasons, super-purity aluminium cannot enter.

In spite of the low finishing costs of bright anodizing, the total costs of material, fabrication and finishing of super-purity aluminium are much higher than those involved in production of plated steel or zinc-alloy die-castings. Finally, after some years of technical development, there are still no large-scale applications of bright-anodized super-purity aluminium. This might be due to lack of confidence

in the finishing technique, or to insufficient supply of the material itself.

Supporting the case for anodized aluminium, E. E. SPILLETT spoke of widening use of this type of finish, the 'quality' appearance of anodized coatings, ease of processing, and the attractive strength/weight ratio.

T. E. SUCH seconded Castell in upholding the superiority of nickel/chromium-plated finishes. He called attention to the technical difficulties of chemical polishing and anodizing:—the high and uncontrollable rate of dissolution in the Erftwerke polishing process; the need for cooling the sulphuric-acid anodizing electrolyte below 55°C., and the difficulty of providing pure boiling water or steam at 212°F. in the normal plating shop. He also suggested that a thickness of anodic film of 0·0004 in. was necessary for satisfactory resistance to attack in industrial atmospheres. Further difficulties likely to prevent spectacular advance of anodized super-purity aluminium concerned the lack of 'know-how' on pressing techniques, and the tendency for contamination of the aluminium surface by 'pick-up' during processing, or by oxide inclusions. Finally, he pointed out that bad anodizing was just as possible as bad nickel/chromium plating, on which many of the present complaints were based.

After a lengthy general discussion, *the motion was defeated by* 43 *votes to* 27.

Nickel Plating of Molybdenum

S. S. BRENNER: 'High-Temperature Adherence of Nickel Plates to Molybdenum.'

Plating, 1956, vol. 43, Sept., pp. 1143-4.

Various methods have been proposed for protection of molybdenum against oxidation at high temperatures. Use of electrodeposited coatings has the advantage of simplicity, but difficulty is found in obtaining good adherence of other metals to molybdenum: on heating, the electrodeposited coatings tend to buckle and blister.

KORBELAK reported that adherent coatings could be obtained by application of a chromium strike followed by a nickel strike, and final plating with any metal suitable as an outside coating (see *Plating*, 1953, vol. 40. pp. 1126-31: *Nickel Bulletin*, 1953, vol. 26, No. 12, pp. 205-6).

The present paper describes an alternative procedure. The recommended cycle is as follows:—

Degrease by conventional methods
Etch by conventional methods
Brass strike from a cyanide solution operated at 40°C., at a current density of 0·2 amp./cm², for 10–60 seconds
Anneal at 750°-900°C. for 10 minutes, in a non-oxidizing atmosphere
Electroplate with nickel, to the desired thickness.

In the tests reported, specimens of molybdenum so coated were heated for 30 minutes at 900°C. Of 52 samples so treated, only 3 showed slight blistering.

One effect of the brass strike and the subsequent heat-treatment is illustrated in the report. During heating the zinc evaporates and small 'islands' of copper are formed. It is posited that the nickel plating is held down by these 'islands', so that there is sufficient diffusion welding between the nickel and the molybdenum to prevent blistering and buckling.

In addition to nickel-plated molybdenum, specimens of nickel-plated tungsten and copper-plated molybdenum were also prepared, using the brass strike. All showed good adherence at high temperatures, and it is suggested that the use of a discontinuous intermediate flash-coating may be a generally useful method of obtaining high-temperature adherence between two metals of widely different thermal coefficients of expansion. On heating, the isolated region of the flash coating is able to expand freely, laterally, without buckling, and diffusion can readily occur, because of the continuous contact between the base metal and the flash coating. When the discontinuous flash coating is widely dispersed, and the final plating is held down at the isolated regions, it is not possible to form blisters of any appreciable height. The relation between the radius of the base metal area encircled by the flash-coated regions or 'islands' and the maximum height of a blister which can form due to thermal expansion, is shown by an equation.

(*see also* following abstract.)

Electrodeposition of Nickel and Other Metals on Beryllium

J. G. BEACH and C. L. FAUST: 'Electroplating on Beryllium.'

U.S. Atomic Energy Commission, Report BMI-732, 1952: Declassified Nov. 9, 1955; 46 pp.

The report, covering work done at the Battelle Memorial Institute, describes two methods for electroplating beryllium. One procedure involves electrochemical and chemical activation of the beryllium surfaces for direct plating with nickel, iron, copper, aluminium, silver, tin and speculum. The other method is based on the application of a replacement film of zinc on the beryllium surface, followed by strike plating with copper or nickel from baths suitable for plating on zinc. After the strike plating, electrodeposition is by methods generally used for plating on the metal which has been selected for the strike. Method 2 is similar to that used for electrodeposition on aluminium and magnesium.

The diffusion of electroplated metals (zinc, copper, chromium, nickel and iron) with beryllium was investigated, to determine the characteristics of the alloys formed at elevated temperatures. Strong solid-solution alloys appeared to give satisfactory bonding, but formation of compounds usually resulted in brittle interfacial layers, and weakened a bond which might have been good in the as-plated condition. The results of the diffusion experiments with nickel and beryllium indicate that the use of electrodeposited nickel on beryllium should be considered only for applications involving temperatures below 660°F. (350°C.).

Nickel Plating of Metals used in Nuclear Plant

C. L. FAUST and J. G. BEACH: 'Plating on Unusual Metals.'

Plating, 1956, vol. 43, Sept., pp. 1134–42.

Developments during the past decade, particularly those in the field of nuclear energy, have brought new demands for metals showing strength and corrosion-resistance at high temperatures. Some of the metals which offer properties suitable from the point of view of structure and of stability under working conditions suffer from the disadvantage of having surface properties which limit their adaptability for certain conditions of processing and/or service. Among such metals are aluminium, beryllium, molybdenum, niobium, thorium, titanium, uranium, zirconium, alloys of these metals with other elements, and materials of the type represented by Inconel (nickel-chromium-base alloy) and Stellite (cobalt-base alloy).

Cladding with materials which possess the desired surface stability is one method of obviating the disadvantages of such basis metals, and electrodeposition of coatings has been considered, *inter alia*, for this purpose. This method of coating is assessed by the present authors as having the following advantages and disadvantages:—

Advantages	Disadvantages
Coating thinness not attainable by other methods	Tendency to porosity typical of the crystal structure of electro-deposited metals
Applied without heat or stress	Plate structure influenced by surface state of basis metal
Covers irregular shapes	Need to make electrical contact without a bare spot resulting
Finish-shaped parts can be clad	

The choice of metals which can be used for electrodeposited coatings is limited to those for which plating techniques have already been developed:—aluminium, bismuth, cobalt, copper, gold, indium, iron, manganese, nickel, palladium, platinum, rhodium, tin, zinc and certain alloy platings. Some of the factors involved in the electrodeposition of such metals, on basis metals not usually plated, are considered in this paper, which comprises a report of investigations made at the Battelle Memorial Institute, Columbus, Ohio.

As a general recommendation, the importance of correct surface preparation of the base metals is emphasized. The compositions of typical baths used for electrodeposition of aluminium, bismuth, copper, iron, nickel and zinc are then illustrated, as an introduction to a review of the types of solution and conditions suitable for activating and plating of beryllium, zirconium, molybdenum, bismuth and Inconel.

A further section of the paper deals with alloying by diffusion at the interface between the cladding and the basis metals. Such alloying, which may occur at elevated temperatures, can have either beneficial or deleterious effects: the influence of diffusion is reviewed in relation to the production of electrodeposited/diffusion coatings on beryllium, zirconium, niobium, molybdenum and bismuth.

A special method has been developed for testing the adherence of plated coatings made on 'unusual' metals (see *Jnl. Electrochemical Soc.*, 1953, vol. 100, p. 276). Results obtained by that method are reported, as obtained on nickel coatings plated on zirconium.

Electrodeposition of Nickel on Zirconium

W. C. SCHICKNER, J. G. BEACH and C. L. FAUST: 'Electroplating on Zirconium and Zirconium-Tin.'

U.S. Atomic Energy Commission Report BMI-757, July 1, 1952; Declassified Nov. 1955; 17 pp.

An earlier report had described a method for applying adherent electroplated metals to zirconium. The method described depends on four operations: etching, electrodeposition, pre-baking and heat-treatment.

The present report deals with diffusion bonding of electroplated nickel to zirconium and zirconium-tin alloys, an effect which is obtained by etching in a solution containing ammonium fluoride and hydrofluoric acid, plating from a nickel sulphate/nickel chloride bath, and diffusion heat-treatment.

The thickness of electroplated nickel proposed as optimum for diffusion bonding is 1 to 2 mils. About 0·5 mil. of the nickel alloys with the zirconium, leaving one-half or more as an unalloyed plating. On this coating additional nickel or other coating can be superimposed. If the initial diffusion coating is too thick, separation of the as-plated bond occurs during heat-treatment, as a result of a difference in thermal expansion between the base and the plating metals.

Chromium can be deposited over nickel diffusion coatings on zirconium, but chromium deposited directly on etched zirconium-base materials exfoliates, as a result of the internal stress present in deposits made from the usual chromic-acid plating baths. Modified chromium-plating baths containing fluoride or fluoride complexes did not give satisfactory results.

Co-deposition of Nickel and Germanium

P. R. SUBBARAMAN and J. GUPTA: 'Electrolytic Co-deposition of Germanium from Aqueous Baths.'

Jnl. Scientific Industrial Research (India), 1956, vol. 15B, June, pp. 306–11.

Report of a study of co-deposition of germanium with copper, silver, nickel and cobalt. The readiness with which germanium is co-deposited with copper, nickel and cobalt can be used for recovery of germanium from ammonium-oxalate extracts of coal ash and flue dust.

Cavitation-Erosion of Electrodeposited Nickel

See abstract on p. 219.

NON-FERROUS ALLOYS

Low-Temperature Properties of Nickel Alloys

INTERNATIONAL NICKEL CO., INC.: 'Some Properties of Inco Nickel Alloys at Low Temperatures.'
Published 1956; 5 pp.

Tabular summary of the properties of nickel, Duranickel, the Monel series of nickel-copper-base alloys, and nickel-chromium alloys of the Inconel, Inconel X and Incoloy types.

The information given includes the limiting chemical composition of the respective materials, their physical constants in wrought and cast forms, and their tensile properties, hardness and impact strength at normal and at sub-zero temperatures. In most cases the lowest temperature for which values are given is of the order of −300° to −320°F. (−185° to −195°C.).

Nickel Alloys: Literature Review

See abstract on p. 205.

Theoretical Weights of Nickel-base Alloys

HENRY WIGGIN AND CO., LTD.: 'Theoretical Weights of Wiggin Nickel Alloys.'
Publn. 1054*, 1956; 19 pp.

This publication, comprising a series of reference tables, is designed to assist in the calculation of approximate weights of high-nickel alloys in their various mill forms. The figures given are for Monel, but the information relating to that alloy can be made applicable to over 40 other high-nickel materials, by use of conversion factors which are included in this brochure.

The information covers material in the following forms:—round wire, plate, strip, sheet, cold-drawn seamless tubes, rounds, squares and hexagons, flats and Whitworth hexagon bar. A comparative wire table shows gauge and corresponding S.W.G. and B. and S. dimensions. The information is completed by a list of British Standard and D.T.D. specifications covering Wiggin high-nickel alloys.

Nickel-Manganese Brazing Alloys

See abstract on p. 221.

Magnesium Alloys containing Nickel

J. A. ROWLAND, C. E. ARMANTROUT and D. F. WALSH: 'Experimental Magnesium Alloys containing Nickel, Manganese, Lithium and Aluminium.'
U.S. Bur. Mines Report of Investigations 5250, July 1956; 21 pp.

Although the ready availability and extreme lightness of magnesium are attractive to the engineering industries, some other qualities inherent in the metal have up till now been a serious deterrent to its rapid development as a structural material. The highly positive electrochemical nature of magnesium creates a particularly serious corrosion problem which, although it has been solved for certain specific applications, must receive serious consideration in any newly developed application. Magnesium also has a hexagonal, close-packed crystal structure, and the poor ductility and low malleability associated with such structure have increased the difficulties of fabrication.

For some years past the U.S. Federal Bureau of Mines has been investigating the physical metallurgy of magnesium, with the object of developing new magnesium-base alloys which would lead to more general utilization of the metal. The progress of that investigation, up to January 1955, is described in this report.

In the preliminary stages various types of binary and ternary magnesium-base alloys were briefly studied. The materials which received sufficient attention to justify separate consideration were the binary alloys containing magnesium, nickel or lithium, and the ternary alloys containing manganese with nickel, with lithium, or with lithium+aluminium. The results obtained with such materials are described in this report.

The experimental data reported show that the magnesium-nickel and magnesium-nickel-manganese series offer little promise of being useful commercial materials, due to their extremely low corrosion-resistance and their failure to develop satisfactory mechanical properties. Evidence was obtained, however, that the magnesium-lithium binary and ternary alloys have potential value. Various means of improving such materials were investigated, the most important procedure being that of ageing. In addition, preliminary examination of magnesium-lithium-base alloys containing cerium, antimony or silicon has revealed precipitation-hardening capacities which warrant further investigation.

Electrolytic and Chemical Polishing of Metals

See abstract on p. 204.

Nickel-containing Coinage

See abstract on p. 206.

Cupro-Nickel Condenser Tubes: Service Experience

See abstract on p. 219.

Nickel-Cobalt Alloys for Use in Transducers

C. A. CLARK: 'The Dynamic Magnetostriction of Nickel-Cobalt Alloys.'
Brit. Jnl. Applied Physics, 1956, vol. 7, Oct., pp. 355–60.

The use of magnetostrictive materials in transducers has recently increased considerably: applications include echo-sounders, drilling equipment, ultrasonic cleaning equipment, the ultrasonic soldering iron, and delay lines.

The requirements for magnetostrictive transducer materials are a high rate of change of Joule magnetostriction with magnetic field, good mechanical properties (to enable the core to withstand the induced stresses), and, in many applications, good corrosion-resistance. In order to reduce the eddy currents,

* *We shall be pleased to supply a free copy of this publication.*

metallic materials for such applications should be readily obtainable in the form of thin laminations, and for transducers rated at high powers it is also an advantage for the magnetic core to possess a high Curie temperature, so that some internal heating can be tolerated without adversely affecting the magnetostrictive properties.

In the present work the magnetic properties necessary for high alternating magnetostriction are considered, and criteria by which the quality of materials for ultrasonic transmitters can be assessed are discussed.

It is demonstrated that two binary nickel-cobalt alloys containing, respectively, about 4·4 and 18·4 per cent. of cobalt, are particularly suitable for use as transducer materials. The relevant properties of these alloys are compared with those of nickel-zinc ferrites, cobalt-iron alloys containing small amounts of chromium or of tungsten, and nickel.

Recommendation of the use of the nickel-cobalt alloys is based on examination of a range of alloys containing less than 0·1 per cent. up to 49·6 per cent. of cobalt.

Nickel-Palladium Alloys

E. P. WOHLFARTH: 'The Electronic Properties of Nickel-Palladium Alloys.'

Jnl. Physics and Chemistry of Solids, 1956, vol. 1, Sept.-Oct., pp. 35–8.

The magnetic properties of nickel-palladium alloys are discussed on the basis of the collective electron treatment of ferromagnetism.

See also—

A. I. SCHINDLER, R. J. SMITH and E. I. SALKOVITZ: 'Preliminary Electrical-Resistivity Measurements of the Nickel-Palladium Alloy System', *ibid.*, pp. 39–41.

Electrical-resistivity measurements were made on a series of nickel-palladium alloys, and it was observed that resistivity reaches a maximum at approximately 70 at./per cent. palladium at 4·2°, 77° and 300°K. (−269°, −196° and +27°C.).

Spectrophotometric Determination of Aluminium in Nickel and Nickel Alloys

R. J. HYNEK and L. J. WRANGELL: 'Spectrophotometric Determination of Aluminum in Ferrous and Non-Ferrous Alloys. Application of 8-Hydroxyquinaldine.'

Analytical Chemistry, 1956, vol. 28, Oct., pp. 1520–7.

It has been observed that 8-hydroxyquinaldine does not react with aluminium, but does react with many of the elements which interfere with determination of that element. This property is utilized in a widely applicable method for the elimination of some interferants, prior to spectrophotometric determination of aluminium-8-hydroxyquinolinate in chloroform at 389 mμ. A mercury cathode partially removes metallic ions. Interferences are ultimately eliminated by adjustment of the pH to 9·2 and use of 8-hydroxyquinaldine, chloroform and hydrogen peroxide. For certain alloys use of the mercury cathode is unnecessary.

It is stated that the method has been applied to a wide variety of standard and commercial alloys containing up to 10 per cent. of aluminium. These include some copper-base alloys, and K Monel (nickel 66, copper 28, aluminium 3, per cent.), also R Monel, nickel weld metal, and straight-chromium stainless steels, all of which are likely to contain only minute percentages of aluminium.

Analysis of Nickel-base Alloys for Thermionic Cathodes

See abstract on p. 206.

NICKEL-IRON ALLOYS

Oxygen in Liquid Nickel-Iron Alloys

H. A. WRIEDT and J. CHIPMAN: 'Oxygen in Liquid Iron-Nickel Alloys.'

Jnl. of Metals, 1956, vol. 8, Sept.; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 1195–9.

Nickel is more resistant to oxidation than is iron, in both the solid and the liquid states. The solubility of oxygen is, however, greater in nickel than in iron. The two metals and their alloys constitute an interesting series of solvents in which the chemical behaviour of oxygen can be studied by methods similar to those used by Chipman in studies on liquid iron (*Trans. Amer. Inst. Mining and Metallurgical Engineers*, 1949, vol. 185, p. 441).

This paper reports a study of equilibrium in the reaction of hydrogen gas with oxygen in liquid nickel, iron, and their alloys, at temperatures of 1500°–1700°C. The equilibrium constant, p_{H_2O}/p_{H_2} [% O], is greater in nickel than in iron by a factor of 45 at 1594°C. In the alloy-steel range the activity coefficient of oxygen is slightly increased by the presence of nickel.

See also—

A. M. SAMARIN and V. P. FEDOTOV: 'Oxygen Solubility in Molten Nickel and in Molten Nickel-Iron Alloys.' *Izvest. Akad. Nauk S.S.S.R., Otdel Tekh. Nauk*, 1956, No. 6, pp. 119–25.

These authors confirmed some of the findings of WRIEDT and CHIPMAN.

Nickel and Nickel Alloys: Literature Review

See abstract on p. 205.

Theoretical Weights of Nickel-base Alloys

See abstract on p. 211.

Low-Temperature Properties of Nickel-Iron Alloy

T. GELA, W. J. LEPKOWSKI and H. M. GADE: 'How Seven Non-Ferrous Metals Perform at Low Temperatures.'

Materials and Methods, 1956, vol. 44, Sept., pp. 116–20.

The authors discuss, in general terms, the factors

which influence the behaviour of metallic materials at low temperatures, and present tabular and graphical data showing the tensile properties, hardness, modulus of elasticity and fatigue characteristics of the following materials, in various forms and conditions:—beryllium-copper, phosphor bronze, silver solder, molybdenum, tungsten, tantalum and Nilvar (36 per cent. nickel–iron alloy). Values reported for Nilvar are shown below.

Resistance of Nickel-Iron Alloys to Mercury

See abstract on p. 219.

Table I

Form or Condition	Tensile Strength				Yield Strength 0·1% Offset				Elongation % in 2 in.		Rockwell Hardness	Modulus of Elasticity, p.s.i.	
	80°F. (27°C.)		−100°F. (−73°C.)		80°F. (27°C.)		−100°F. (−73°C.)		80°F. (27°C.)	−100°F. (−73°C.)	80°F. (27°C.)	80°F. (27°C.)	−100°F. (−73°C.)
	p.s.i.	t.s.i.†	p.s.i.	t.s.i.†	p.s.i.	t.s.i.†	p.s.i.	t.s.i.†					
Sheet*	76,000	34·0	101,000	45·0	62,000	27·5	76,000	34·0	26·6	29·5	R_b82	21·8 $\times 10^6$	19·7 $\times 10^6$
Sheet* (V-notched)	84,000	37·5	107,000	48·0	—	—	—	—	2·1	2·0	—	—	—

* Rolled to reduction of area of about 5% † To nearest half ton.

Table II

Form or Condition	Fatigue Strength*				Endurance Ratio	
	80°F. (27°C.)		−100°F. (−73°C.)		80°F. (27°C.)	−100°F. (−73°C.)
	p.s.i.	t.s.i.†	p.s.i.	t.s.i.†		
Sheet	26,000	11·5	30,000	13·5	0·33	0·30

* At 2×10^7 cycles. † To nearest half ton.

Table III Tension-Impact Properties

Form	Temperature		Impact Strength ft.-lb./sq. in.	Rockwell Hardness
	°F.	°C		
0·25-in. sheet	80 −100	27 −73	6,010 6,290	R_b84
0·25-in. sheet (V-notched)	80 −100	27 −73	660 520	

Table IV Charpy V-Notch Impact Data

Form or Condition	Rockwell Hardness	Impact Strength, ft.-lb.	
	80°F. (27°C.)	80°F. (27°C.)	−100°F. (−73°C.)
Annealed	R_b76	218	162
Hard	R_b98	97	77

CAST IRON

S.G. Iron: Methods of Production and Applications

W. W. BRAIDWOOD: 'Latest Developments in Spheroidal-Graphite Iron.'

Foundry Trade Jnl., 1956, vol. 100, May 17, pp. 321–30; disc., *ibid.*, vol. 101, July, pp. 47–50.

Reprint issued by MOND NICKEL CO., LTD., 1956; Publn. 1102*; 15 pp.

The paper describes progress which has recently been made in production methods, with particular reference to techniques in which treatment is by means of metallic magnesium. It also comments on some of the properties of S.G. iron and draws attention to some applications which have already become firmly established.

flake-graphite iron and may acquire a considerable degree of ductility, together with an impact resistance many times greater than that of flake-graphite iron.

The specification covers three types of iron:—

'Type 1. Those with a mainly pearlitic matrix, characterized by high tensile strength, but in which ductility and resistance to impact are of less importance.

'Type 2A. Those with a mainly ferritic matrix of moderately high tensile strength, in which high ductility and toughness are of great importance.

'Type 2B. Those with a ferritic matrix, in which resistance to impact is of paramount importance.'

The requirements for the respective types are tabulated below.

Type of Iron	Tensile Strength (min.) t.s.i.	0·5 per cent. Permanent Set Stress (min.) t.s.i.	Elongation (min.) %	Impact Value (min.)	
				Average † ft.-lb.	Individual ft.-lb.
Type 1	35	—	2	—	—
Type 2A ..	27	18	12	—	—
Type 2B ..	24	15	17	10	9

† Average of set of three on one test sample.

S.G. Iron Data Sheet

'Nodular or Ductile Irons: Materials Data Sheet.'

Materials and Methods, 1956, vol. 44, Sept., pp. 143, 145.

Tabular data on the composition and properties of six types of S.G. iron, including normalized, annealed, oil-hardened and tempered, heat-resistant, and austenitic classes. Thermal treatments applicable to the respective types of iron are shown, and some applications are listed.

S.G. Iron: B.S. Specification

BRIT. STANDARDS INSTN.: 'Iron Castings with Spheroidal or Nodular Graphite.'

B.S. 2789: 1956; 11 pp. Price 3s. 6d.

In this specification, the first British Standard to be issued for cast iron of spheroidal-graphite structure, the nature of the material is defined and its inherent characteristics are briefly described. Attention is drawn to the fact that this type of iron has properties fundamentally different from those of normal grey iron containing flake graphite, but similar in some respects to those of malleable cast iron. It possesses greater tensile strength than

It is also specified that for Type 2A castings the Brinell hardness shall not exceed 187, and that for Type 2B castings it shall not exceed 159.

For special applications impact tests may be required to be made at low temperatures, in which case the test-temperature range and the minimum impact value acceptable are to be the subject of agreement between purchaser and manufacturer at the time of placing the order.

Pearlitic irons of Type 1 are susceptible to practically all forms of heat-treatment, including quenching and tempering, induction- or flame-hardening, and normalizing. When suitably annealed the irons yield the ductile and easily machined materials covered by Types 2A and 2B.

Materials intermediate between the mainly pearlitic and mainly ferritic grades may be obtained by adjustment of the composition or by appropriate heat-treatment, and the iron may also be alloyed, to produce acicular, martensitic and austenitic irons. Major interest at present centres on the classes mentioned above, for which there is a firm basis of experimental and production data. At a later date further clauses may be added to the specification, as the need arises.

Details are given of the test pieces which are to be used for determination of tensile properties and of a bar suitable for bend tests.

* *We shall be pleased to supply a free copy of this publication.*

Applications of S.G. Iron

'Miscellaneous Applications of S.G. Iron.'
Nickel Topics, 1956, vol. 9, Parts 1–6.

Successful applications of S.G. iron for which service records have recently been published include the following:—

Lead pots, furnace doors and frames; petrol-engine crankshafts in farm equipment; rolls for hot-roughing and working; pipe fittings; glass-bottle moulds; web rolls used for forming the rim, tread and flange contours of rolled-steel railway wheels; brake bands on large forging presses; bottom and side plates in coke-quenching cars; spindle housings on surface grinders. The improvements effected by introduction of S.G. iron in these applications variously include increased life, more satisfactory service, and lowered costs.

S.G. Iron in Tankers

M. PARIS and B. DE LA BRUNIÈRE: 'Ductile Iron: Corrosion-Resistance in Sea Water and Petroleum-Tanker Service.'
Nat. Assocn. Corrosion Engineers, Preprint, Mar. 1956; 13 pp.

This paper reviews the results of laboratory tests and service experience with S.G. iron pipe in tankers. Results of corrosion tests under various conditions are given in full, confirming general experience that S.G. iron has approximately the same corrosion-resistance as grey cast iron, and that in most cases its rate of corrosion is substantially less than that of steel. Moreover, with cast irons the corrosion rate tends to slow down with time, thus widening the differential between these materials and steels.

The results reported in this paper cover tests in sea water under various conditions, and in distilled water, as well as in mineral and organic acids. The account of service tests in tankers is, however, of major importance. These tests have shown that after five years' service S.G. iron pipes are still in good working condition and that corrosion appears to have completely ceased. Under similar conditions steel pipes always require replacement. S.G. iron steam-heating coils, carrying steam at 150°C., are absolutely intact, showing no trace of serious corrosion, whereas steel pipes in the same system have had to be removed on account of severe deterioration. Reference is made to the fact that 40 tankers are now equipped with S.G. iron piping, and service reports are entirely satisfactory.

CONSTRUCTIONAL STEELS

Complex Low-Alloy Steel for Pressure Vessels

J. M. HODGE and L. C. BIBBER: 'A Low-Alloy Quenched and Tempered Steel for Pressure Vessels.'
West of Scotland Iron and Steel Inst., Paper No. 492, Oct. 19, 1956; 41 pp.

In the introduction the authors briefly summarize the characteristics required in pressure-vessel steels, and subsequently give a detailed report on 'T-1', a steel which has been developed in the U.S.A. to meet these requirements. The chemical composition of the steel is as given below:—

	%		%
Carbon ..	0·10-0·20	Nickel ..	0·70-1·00
Silicon ..	0·15-0·35	Chromium ..	0·40-0·80
Manganese ..	0·60-1·00	Molybdenum	0·40-0·60
Sulphur ..	0·050 max.*	Vanadium ..	0·03-0·10
Phosphorus	0·040 max.*	Copper ..	0·15-0·50
		Boron ..	0·002-0·006

* Phosphorus 0·035 per cent. max. and sulphur 0·040 per cent. max. for firebox quality.

In the paper details are given of methods of manufacture and of tests which have been carried out to establish the suitability of the steel for pressure-vessel applications. Attention is directed to the fact that much of the information has already been published: references to other reports are given in the *bibliography*: see also *Nickel Bulletin*, 1955, vol. 28, No. 12, pp. 220, 221.

Impact-Testing Symposium

See abstract on p. 202.

Electrolytic and Chemical Polishing of Metals

See abstract on p. 204.

Welding of High-Tensile Steels

C. L. M. COTTRELL, K. WINTERTON and B. J. BRADSTREET: 'The Weldability of High-Tensile Structural Steels.'
Reprint of *Ministry of supply report* W.R.(D) 1/55; issued May 1956; vii+79 pp. and figures.

The work described was carried out over the period 1948–54: the report summarizes work undertaken by the British Welding Research Association on behalf of the Ministry of Supply. It consists mainly of a chronological account of the development of the B.W.R.A. Controlled Thermal Severity Test for assessment of weldability, the use of continuous-cooling transformation data in correlating weldability and composition, and the application of approved tests to a number of selected steels.

The report is in four main sections:—

(1) Weldability of a low-alloy manganese-molybdenum steel for a special high-strength structure

(2) Weldability and properties of a series of experimental manganese-nickel-chromium-molybdenum-(vanadium)-steels

(3) The mechanism of hard-zone cracking, as revealed by various tests

(4) The influence of hard-zone cracking on fatigue life of fillet welds.

Influence of Zinc-Phosphate Coating in Flash-Welding of Low-Alloy Steel

J. F. YOUNG and A. PHILLIPS: 'The Effects of Zinc-Phosphate Coating on Flash-Welding of Steel Tubing.'

Welding Jnl., 1956, vol. 35, Sept., pp. 416S–20S.

Flash-welding is used by the Douglas Aircraft Company for fabrication of landing-gear components, engine mounts and control-actuating members, and on account of the critical nature of such applications the welds must be of high quality. The steel used is of the following type:—

Composition of Steel Used in Flash-Welding Studies

	%
Carbon	0·029
Silicon	0·29
Manganese	0·81
Sulphur	0·017
Phosphorus	0·006
Nickel	0·60
Chromium	0·56
Molybdenum	0·17
Copper	Trace
Iron	Balance

Destructive tests carried out as routine control on sample welds, before beginning production runs of flash-welding, comprise notch-bending, tensile tests, and examination of fracture. Brittle bend tests have in some cases been experienced, with a flat break through the weld zone.

Work described in this paper demonstrated that this effect is due to the presence of zinc phosphate used by some tube producers as a coating, to facilitate drawing.

During flash-welding the zinc volatilizes as zinc oxide, but the phosphorus from the coating can enter the flash-weld zone during the welding operation. The resultant joint will show, in the as-welded condition, lowered notch-bend strength and/or flat breaks through the weld plane. It was found also that the Charpy V-notch impact-transition range was displaced to a considerably higher temperature by the introduction of phosphorus into specimens locally heated in the region of the notch.

Removal of the zinc-phosphate coatings, to a degree ensuring satisfactory flash welding, can be effected by treatment in strong caustic solutions at 200°F. (93°C.) or in dilute sulphuric acid at room temperature. In cases where tubing has been heated above 1300°F. (705°C.) before cleaning, complete removal of the coating is not possible.

Carbon Migration in Welded Joints

See abstract on p. 221.

HEAT- AND CORROSION-RESISTING MATERIALS

Effect of Vacuum Melting on Nickel-base High-Temperature Alloys

'Vacuum Melting Improves Properties of New Alloy.' *Iron Age*, 1956, vol. 178, Sept. 20, pp. 100–1.

The article deals with the improvement in properties which can be obtained by vacuum melting, as compared with air melting, of Hastelloy R-235* and other high-temperature alloys.

As an example of the enhanced properties so obtainable, it is reported that stress-to-rupture for 100 hours at 1500°F. (815°C.) is 20 per cent. higher for the vacuum-melted alloy than for the comparable air-melted material. The strength of this alloy up to 1750°F. (955°C.) is an outstanding feature: typical average stress-to-rupture in 100 hours at 1500°F. (815°C.) is 38,000 p.s.i. (17 tons per sq. in.) for bar stock, and about 37,000 p.s.i. (16·5 tons per sq. in.) for sheet. The alloy also shows good impact strength. Solution-annealed bar is claimed to have an average Charpy V-notch impact strength of 107 ft.-lb. at room temperature.

As a further example of the benefits of vacuum melting, reference is made to Hastelloy F†, in which close control of carbon is a major factor in obtaining maximum corrosion-resistance. Comparisons are made of the behaviour of air-melted and vacuum-melted samples of this alloy, in the standard boiling 65 per cent. nitric-acid control test.

Nickel and Nickel Alloys: Literature Review

See abstract on p. 205.

* Typical composition:- chromium 15, iron 8, molybdenum 5·5, titanium 2·5, aluminium 2, carbon 0·15, per cent., balance nickel.

† Typical composition:- chromium 21-23, nickel 44-47, molybdenum 5·5-7·5, niobium + tantalum 1·75-2·5, carbon 0·08 max., with permissible small amounts of manganese, silicon, tungsten, cobalt, balance iron.

Low-Temperature Properties of Nickel and Nickel Alloys

See abstract on p. 211.

Properties of Alloys of the Nimonic Series

W. BETTERIDGE and A. W. FRANKLIN: 'Development of Nickel-Chromium-base Alloys for High-Temperature Service.'

Metal Treatment and Drop Forging, 1956, vol. 23, Sept., pp. 343–8; Oct., pp. 385–9.

Based on a paper presented in 1955 to La Société Française de Métallurgie, in Paris.

Following brief reference to the established nickel-chromium-base alloys and early work on the modification of their properties by additions of aluminium and titanium, an account is given of the development, properties and uses of alloys of the Nimonic series (nickel-chromium-(cobalt)-base, hardened with titanium and aluminium). The subject is dealt with in the sections shown below:—

Composition

Attention is directed to literature on the relevant ternary systems, and a constitutional diagram resulting from complementary investigations of the quaternary nickel - chromium - titanium - aluminium system is shown. A report is made of studies of the effect of constitution on the stress-rupture properties of nickel-chromium-base alloys: the structures of alloys containing various proportions of titanium and aluminium are illustrated, demonstrating the effect of variation in the amount of the addition element present. The influence of heat-treatment, on the nature of the precipitates formed is illustrated. The authors then describe structural modifications and changes in solubility of the additional elements resulting from the substitution of 20 per cent. cobalt for a similar amount of nickel.

Heat-Treatment

The significance of heat-treatment, in ensuring optimum creep-resistance, is emphasized, with illustrations showing the influence of temperature of (*a*) solution treatment, (*b*) precipitation-hardening treatment. The possibility of obtaining desired combinations of high-temperature properties is demonstrated.

Creep Properties

Creep and stress-rupture data are tabulated for Nimonic 80, 80A, 90, 95 and 100. The various methods of presenting creep data are discussed, and graphs show, for various Nimonic alloys, creep against temperature, stress against temperature for rupture in 100 hours, and other long-term test data. Attention is directed to the fact that in development of creep-resisting alloys it is generally found that the improved creep-resistance obtained by increase in the proportion of alloying elements is accompanied by a reduction in the total creep extension measured before fracture. It is, however, important to note that a low extension of this nature does not necessarily imply brittleness or lack of ductility under overload conditions. Tests recorded in the paper show that the ductility of Nimonic 80A is retained during a long-time creep test in conditions which are known to lead eventually to creep fracture with a total extension of only about 2 per cent. It has been shown that a further advantage of the Nimonic alloys is their retention of strength under notched conditions: in some circumstances the presence of a notch may even have a strengthening effect.

Fatigue Properties

The fatigue properties of these alloys at elevated temperatures have been determined by two methods: (1) rotating-bending, (2) tensile-compression. The rotating-bend tests have indicated that fatigue strength of such alloys increases with increase in creep-resistance. In the tensile-compression tests, which are still under way, findings to date suggest that for a given life the alloys can sustain a greater stress when a small fluctuating stress is superimposed on a steady stress. This observation has been made also by other workers, but no explanation has yet been proposed for the effect.

Reference is made to the possible rôle of oxidation in fatigue.

Short-time Properties

For information on short-time properties, over a range of temperatures, the reader is directed to the paper by WARD and TALLIS presented to the American Society for Testing Materials in 1955 (*Special Tech. Publn.* No. 174, 1956, pp. 135–45: *Nickel Bulletin*, 1955, vol. 28, No. 9, p. 150).

Oxidation- and Corrosion-Resistance

The Nimonic alloys are all characterized by the excellent resistance to oxidation inherent in the binary nickel-chromium alloys from which they are derived, and this resistance is enhanced in the Nimonic alloys by the presence of aluminium. The scaling-resistance varies somewhat within the series: Nimonic 100, the alloy showing the highest creep-resistance, is also the most resistant to oxidation. The nickel-chromium-base alloys are also more resistant than other high-temperature materials to the accelerating effect of vanadium pentoxide on oxidation; from this point of view the cobalt-free alloys of the series are to be preferred to those in which a considerable amount of this element is present.

As an example of the progressive improvement which has been effected by research on this series of alloys, it is noted that Nimonic 80, which was introduced in 1941, would fracture in 100 hours under a stress of 12·7 tons per sq. in. at a temperature of 720°C., whereas Nimonic 100, the latest member of the series, which was announced in 1955, will sustain the same stress for 100 hours at a temperature of 860°C. Corresponding improvement in fatigue strength and in short-time tensile and torsion properties at elevated temperatures is associated with the increasing creep-resistance.

Theoretical Weights of Nickel-base Alloys

See abstract on p. 211.

Effect of Cold Working on the High-Temperature Properties of Austenitic Steel

R. A. LULA: 'Cold-Worked 301 Stainless Still Strong at 800°F.'
Materials and Methods, 1956, vol. 44, Sept., pp. 100–2.

Further to work reported in a paper to the American Society of Mechanical Engineers (see *Nickel Bulletin*, 1956, vol. 29, Nos. 10–11, p. 193), the author of this note presents additional data confirming the beneficial influence of cold-working on the high-temperature properties of 18–8 chromium-nickel steel. Stress-rupture and creep curves at 800°F. (425°C.) are shown for steel in the fully-hard condition, short-time mechanical properties in the range room temperature to 900°F. (480°C.) are tabulated, and the room-temperature properties are given for cold-worked material after long exposure at 400°, 600° or 800°F. (205°, 315° or 425°C.). Some comparison is made between the tensile strength of cold-worked 18–8 steel and that of other high-temperature materials, at room temperature up to 1000°F. (538°C.).

Electrolytic and Chemical Polishing of Metals

See abstract on p. 204.

Cladding of Zirconium with Nickel and Nickel Alloys

H. A. SALLER, J. R. KEELER and E. R. SZUMACHOWSKI: 'The Cladding of Zirconium.'
U.S. Atomic Energy Commission, Report BMI-717, 1951: Declassified Nov. 9, 1955; 13 pp.

Report on attempts to improve the corrosion-resistance of zirconium by roll-cladding with corrosion-resisting materials: the claddings used were nickel, Monel, Inconel, titanium and 18–8 chromium-nickel steel. The resulting products were evaluated by determination of mechanical properties of the bonds, which were also metallographically examined and subjected to bend, chisel, and tensile tests. The stability of the cladding during thermal cycling was also investigated.

With the exception of titanium, all the materials used formed compounds at the zirconium interface, and the resulting bonds had poor mechanical properties. The titanium-zirconium bond showed good strength and ductility and there was no tendency to crack during thermal cycling.

An effort was made to overcome the problem of the brittle intermediate compounds by use of a barrier metal which would form ductile bonds with zirconium and also with the cladding metals. Diffusion couples were made between zirconium and copper, iron, molybdenum, platinum, silver, tantalum, and cartridge brass, but in all cases these sandwich-type couples behaved in a manner indicating that the metals suggested as barriers formed hard brittle diffusion products with zirconium.

Resistance of Nickel-Chromium Stainless Steels to Mine Waters

S. G. ASH *et al.*: 'Corrosive and Erosive Effects of Acid Mine Waters on Metals and Alloys for Mine-Pumping Equipment and Drainage Facilities.'
U.S. Bur. Mines, Bull. 555, 1955; 46 pp.

Severe corrosion of pumping equipment handling acid waters of anthracite mines in Pennsylvania has for many years been a heavy economic disadvantage. This report gives results of research, conducted jointly by the Federal Bureau of Mines and Armco Steel Corporation, with a view to overcoming this problem. The report contains data on laboratory and field tests on 25 different metallic materials subjected to various severely corrosive waters, the compositions of which are detailed.

The tests made were of two types:—

(1) *immersion tests*, using spool-type specimen holders, suspended in the sumps, main pump discharges or flumes from pump discharges in receiving streams at four mines;
(2) *revolving-spindle tests*, used to study the effect of velocity on corrosion. During part of these tests fine abrasives were incorporated in the water, to simulate severely abrasive conditions in pumps.

On the basis of behaviour in both tests, 18–8 chromium-nickel steels, with or without molybdenum, also three types of straight-chromium stainless steel, and 17–4 PH and 17–7 PH hardenable chromium-nickel steels, gave adequate resistance to corrosion. Cast stainless steels of the 28–10, 18–10–Mo and 25–5 chromium-nickel types, and titanium also proved satisfactory. Although various types of bronze differed among themselves in degree of corrosion-resistance, all were markedly inferior to the stainless steels. Results on other steels tested indicate that a minimum of 11–12 per cent. of chromium is required to prevent corrosion in acid mine waters of the compositions encountered in the anthracite mines.

Stress-Corrosion Cracking of Austenitic Steels

J. G. HINES and T. P. HOAR: 'The Stress-Corrosion Cracking of Austenitic Stainless Steels. Part II. Fully Softened, Strain - Hardened, and Refrigerated Material.'
Jnl. Iron and Steel Inst., 1956, vol. 184, Oct., pp. 166–72.

In previous papers the authors have described the stress-corrosion cracking of a number of 18–8 type stainless steels in boiling aqueous magnesium-chloride solution (42 wt-% $MgCl_2$), and have discussed the mechanism of cracking. The materials used in the earlier experiments were in wire form, and in the as-received condition had been commercially fully softened, but slightly cold-worked by subsequent coiling and uncoiling.

The work now reported deals with the behaviour of wires of similar material in three conditions:—

(1) Fully softened after uncoiling
(2) Deliberately strain-hardened
(3) Refrigerated at −184°C.

The effects produced in steels of three compositions were examined:—

18–8 chromium-nickel

18–8 chromium-nickel titanium-stabilized

18–8 chromium-nickel containing 3 per cent. molybdenum.

The fully softened steels stressed in tension and exposed to aqueous magnesium-chloride solution at 154°C. gave stress-corrosion cracking qualitatively similar to that previously observed in the same steels in the as-received condition (fully softened and slightly cold-worked).

It was observed, however, that certain duplex steels, which in the as-received condition fractured at zero applied stress, did not, when softened, fracture at applied stresses less than about two-thirds of the 0·1 per cent. proof stress.

Plastic strain or refrigeration treatments applied to fully softened straight 18–8 steel shortened the time to fracture at any particular applied stress, and increased the density of the cracking. The quasi-martensite formed either by strain or refrigeration is considered to provide surface regions especially active for the initiation of stress-corrosion cracks, but it probably plays little part in propagation of the cracks.

The results now reported are in general agreement with the mechanism of stress-corrosion cracking advanced by the authors in their earlier paper.

Cupro-Nickel Condenser Tubes: Service Experience

H. A. TODHUNTER: 'How to Lengthen Condenser-Tube Life.'

Power, 1956, vol. 100, Mar., pp. 85–7.

This report, made by the Steam Engineer of the Department of Water and Power, City of Los Angeles, California, is based on experience in the Harbor Steam Plant of the Department, which supplies electrical energy to one of the Company's receiving stations. From there it goes to a service area containing about 50 per cent. industrial customers, and also to the distribution network which serves the entire Los Angeles area. The five units of the Harbor Steam Plant have a total capacity of 414,000 kW.

The article reports experience with tubes of aluminium-brass, cupro-nickel, phosphorized and arsenical Admiralty brass, and aluminium bronze. Details are given of the behaviour of the respective types of tubing, and a graph summarizes their relative corrosion-resistance, over various periods, in water circulating through the tubes at about 7 ft. per second.

The following comments are made:—

'*Cupro-Nickel Tubes.* The 70-30 cupro-nickel condenser tubes have shown by far the least pitting of any of the tubes tested. After about 30,000 hours of service most of the pits were less than 0·005 in. deep for the cupro-nickel tubes containing 0·4–0·6 per cent. iron. On the other hand, the 70-30 cupro-nickel tubes with less than 0·2 per cent. of iron had thinned to almost one-half their original thickness after 30,000 hours' service and had lost about 42 per cent. of their weight.

'As a result of this experience we are specifying 70-30 cupro-nickel with an iron content of 0·4–0·8 per cent., instead of a maximum iron content of 0·6 per cent. (A. S. T. M. specification B111-49, which originally specified a maximum iron content of 0·6 per cent., has now been narrowed to provide for a range of 0·4–0·7 per cent.).

'Since none of the banks of cupro-nickel tubes now installed have been replaced, we do not know the ultimate life for this alloy for our particular conditions'.

Tests are now under way to determine the relative merits of iron-containing 70-30 and 90-10 cupro-nickel tubes.

Cavitation-Erosion: Survey of Data

R. TROCK: 'A Study of Cavitation-Erosion.'

Soc. Automotive Engineers, Preprint 758, June 1956; 12 pp. + figures.

Although there is as yet no complete understanding of the mechanism of cavitation-erosion, investigations already reported have established that the following factors affect the pitting rate of metallic materials:—(*a*) hardness, (*b*) porosity and surface discontinuities, (*c*) viscosity, temperature and molecular size of the contacting liquid, (*d*) amplitude of vibration, and (*e*) addition of corrosion inhibitors.

This paper reviews the literature covering various theories of cavitation-erosion, with special reference to those which refer to occurrence of the phenomenon in Diesel engine cylinders. Results already recorded are compared with previously unpublished research data supplied by Studebaker-Packard Corporation. The latter refer, *inter alia*, to cavitation-erosion tests on nickel/chromium-plated Nitralloy steel.

Resistance of Nickel-containing Materials to Mercury

J. F. STRACHAN and N. L. HARRIS: 'The Attack of Unstressed Metals by Liquid Mercury.'

Jnl. Inst. Metals, 1956–7, vol. 85, Sept., pp. 17–24.

The work described, which was carried out in the laboratories of the General Electric Company, Ltd., for the Atomic Energy Research Establishment, formed part of a programme of research on the use of liquid metals as coolants in nuclear reactors. An experimental survey was made of the saturated solubility of most of the metallic elements, bright-annealed and unstressed, in static liquid mercury at room temperature, and of the attack undergone by them at room temperature and at 500°C.

The following techniques were variously used: measurement of change in weight of the specimens, chemical analysis of the solutions, microscopical examination of etched sections of the specimens, and X-ray examination of the products of attack. (The metals were exposed to mercury in the absence of air, in order to avoid complications and ambiguities in the results, since it is believed that the presence of air accounts for many of the discrepancies which have been reported in the literature.)

Attack resulting from immersion in static liquid mercury at 300°–500°C. was studied on bright-annealed and unstressed commercial nickel, Inconel, Nimonic 75, 50–50 nickel-iron alloy, 25–20 chromium-nickel steel, 18–8 chromium-nickel steel, a chromium-silicon valve steel, mild steel, iron, molybdenum and tungsten. In addition to examination by the four techniques listed, the extent of the mercury attack was further determined by evaluation of variation in maximum stress, yield stress, hardness and percentage elongation. The effect, on mercury attack, of removing oxide films, adsorbed gas, and layers of water vapour from the surface of some of the metals and alloys was also examined.

No significant changes occurred in the mechanical properties of iron, molybdenum, some steels and nickel alloys after 2,000 hours in mercury at 500°C. Nickel suffered a decrease in maximum stress, yield stress and elongation. Certain complexities involved in evaluating the behaviour of some of the materials under varying conditions are illustrated by discussion of observations made on nickel.

Severe cavitation-erosion of metals and alloys normally resistant to mercury occurs at room temperature when ultrasonic vibrations of 30 kc./s. are applied. The erosion attack on nickel, which was severe, was quite different from the type of attack suffered under static conditions. Similar tests on Inconel proved that grains in the neighbourhood of cavitation pits were severely strained, implying that high pressures, of several tons per square inch, had developed: this finding qualitatively supports theoretical predictions of high pressures developed by collapsing cavitation bubbles, as advanced by Noltingk and Neppiras (*Proc. Phys. Soc.*, 1950, B, vol. 63, p. 674).

Influence of Nickel Additions on Corrosion-Resistance of Zirconium

D. S. KNEPPEL and T. T. MAGEL: 'Beneficial Effect of Alloy Additions to Zirconium on the Corrosion-Resistance in 600°F. Water.'

U.S. Atomic Energy Commission Report MIT-1092, 1952: Declassified Oct. 18, 1955; 11 pp.

Tests made, under various conditions, at the Massachusetts Institute of Technology have shown that the presence of small amounts of nickel, iron and chromium appreciably enhance the resistance of zirconium to corrosion by high-temperature water (600°F. : 315°C.), and that the beneficial effect of the addition elements is even greater in steam, e.g., at 750° and 900°F. (400° and 482°C.).

S.G. Iron in Tankers

See abstract on p. 215.

Corrosion of Nickel-Chromium-Iron Alloys by Welding Slags

G. R. PEASE: 'Corrosion of Nickel-Chromium-Iron Alloys by Welding Slags.'

Welding Jnl., 1956, vol. 35, Sept., pp. 469S–72S.

Welding specifications are becoming increasingly insistent that after welding all traces of slag be removed from the joint area: this precaution is recognised as especially important in the welding of high-alloy materials. Such insistence is based on practical experience of unsatisfactory behaviour of weldments from which the slag has not been removed, and it is the object of this paper to present some typical examples of the consequences of neglect in this respect, with special reference to the high-temperature service behaviour of welded nickel-chromium-iron alloys. The examples described and illustrated cover:

(1) 25–20 chromium-nickel-iron alloy retorts used for production of magnesium by the Pidgeon process, which failed due to corrosion by slag;

(2) Uncorroded edge welds in a sandwich assembly of Inconel, heated without access of air, demonstrating the rôle of oxygen in causing attack by slag;

(3) Corrosion of Inconel heat-treatment baskets, due in one case to sulphidation effects induced by the presence of slags in a reducing atmosphere and in the other to oxidation in the presence of slags;

(4) Failure of an annealing-furnace muffle, also due to sulphidation induced by sulphur-scavenging, in a reducing atmosphere, by the slags present on the welds.

The second part of the paper reports laboratory tests carried out to provide better understanding of the attack observed in service and of methods of prevention. The tests were designed to determine:

(1) the lowest temperature at which attack by welding slag is likely to occur,

(2) the relative corrosive effects of slags formed by three substantially different Inconel welding electrodes at temperatures of 1300°–2200°F. (705°–1205°C.),

(3) the capacity of typical slags to absorb sulphur, in a potentially damaging sulphide form, during service of inadequately cleaned welded joints in reducing atmospheres.

From these tests the following conclusions are drawn:

All the evidence confirms that welding-slag residues can shorten the useful life of nickel-chromium-iron alloys when used at high temperatures. Corrosive attack can be expected at any temperature above about 1200°–1300°F. (650°–705°C.), occurring by oxidation in oxidizing atmospheres or by sulphidation in reducing atmospheres. Certain slags are more corrosive than others, but all should be held suspect unless proved to be innocuous. In the tests reported in the paper a simple lime-fluorspar type of flux was very corrosive at 2200°F. (1205°C.,) less so at 1800°–2100°F. (980°–1150°C.), and practically non-corrosive at lower temperatures. A lime-cryolite-rutile type was erratic in its behaviour and was surprisingly corrosive at 1400°–1700°F. (760°–925°C.). A lime-cryolite flux was the most corrosive of all: the attack varied from mild to severe over

the range 1300°–2200°F. (705°–1205°C.). Lime-fluorspar, fluorspar-sodium fluoride-graphite, and fluorspar-sodium fluoride slags were found to absorb sulphur in a potentially damaging sulphide form. The rutile-containing slag, the only one which picked up no sulphur in the tests reported, was later shown to be capable of absorbing sulphur from a hydrogen atmosphere containing hydrogen sulphide at a relatively high level. It is therefore not possible to ensure immunity from damage by recourse to a rutile type of flux.

Carbon Migration in Welded Joints

R. J. CHRISTOFFEL and R. M. CURRAN: 'Carbon Migration in Welded Joints at Elevated Temperatures.' *Welding Jnl.*, 1956, vol. 35, Sept., pp. 457S–68S.

Following discussion of the general phenomenon of carbon migration, the authors report tests on various ferritic/ferritic and austenitic/ferritic weld combinations made:

(1) To determine the propensity of the respective composites to carbon migration

(2) To develop a time-temperature relationship which should be capable of predicting, on the basis of short-time high-temperature tests, the extent of carbon migration which would occur in service

(3) To determine the properties on welded joints aged to simulate the extent of carbon migration which would be expected in service.

The composites used in the experiments included:

Carbon steel (four types) with chromium–molybdenum steels of various types

Chromium–molybdenum steel (two types) with 14%–1½% chromium–molybdenum steel

Chromium–molybdenum steel with austenitic nickel–chromium–molybdenum steel

Chromium–molybdenum and chromium–molybdenum–vanadium steels with nickel–chromium–iron alloy (Inconel)

Chromium–molybdenum–vanadium steel with 96% nickel alloy

Chromium–molybdenum–vanadium steel with cobalt–chromium-tungsten alloy

Cobalt–chromium–tungsten alloy with austenitic nickel–chromium–molybdenum steel

The very extensive tests made, which are reported in detail for the respective combinations, confirm that carbon migration in composite weldments can result in lowering of the carbon on one side of the fusion line, and a build-up on the other. The extent of carbon migration depends on the particular alloy combinations involved: it is not strictly a function of the absolute difference in alloy content.

Mechanical tests made on the aged samples did not indicate that carbon migration profoundly affects the properties, but it is recommended that the operation of such welds at temperatures at which carbon migration may occur should be carefully evaluated.

The data obtained in these tests provided a basis for establishing a parameter relationship giving equivalence between time and temperature for carbon migration in composite welded joints.

Nickel-Manganese Brazing Alloys

W. E. SEYMOUR, H. T. SUMSION, L. M. OSIKA, J. F. DUFFEY and L. S. DeLUCA: 'The Causes of Brittle Failure of Nickel-Manganese Brazing Wire and Recommendations for its Prevention.'

U.S. Atomic Energy Commission, Knolls Atomic Power Laboratory Report KAPL 1309, Feb. 12, 1955; 21 pp. + figures.

A 60 per cent. manganese, 40 per cent. nickel alloy, used in the form of 0·030 in. wire, has been found suitable for torch brazing of stainless steel without a flux. The corrosion-resistance of this alloy and its melting point are attractive characteristics, but it has proved to be susceptible to brittle fracture during storage prior to use. The work covered by this report was carried out to investigate the defect, and some remedial measures are suggested, see below.

Metallographic examination was made of various specimens of sheet and wire which had been cold-worked, and quenched or furnace-cooled from temperatures of 750°–900°C. X-ray diffraction data were obtained on sheet specimens over the range room temperature to 900°C., and measurements of electrical resistance were made, on a 2-in. long 30-mil. wire, during slow heating and cooling, to locate any equilibrium transformation points. The isothermal kinetics of the transformations were also studied from room temperature to 500°C., in steps of 100°C.

The results indicated that the primary cause of the brittleness is precipitation of a face-centred-tetragonal phase of manganese-nickel in the grain boundaries of a face-centred-cubic matrix. Cooling of the alloys at 1½C°. per minute produced a condition of glass brittleness. A second cause contributing to brittleness is the localized mechanical failure of the material during swaging and drawing operations, with formation of short spiky microcracks normal to the surface of the wire. These cracks, which generally intersect the surface, occur intermittently along the length of the wire.

Annealing between the stages of the working process is recommended as a remedial measure, and rapid quenching from 850°–900°C. after the final working operation would render the 60–40 alloy immune from brittle fracture for longer periods than can at present be ensured. The tendency to embrittlement can be eliminated by raising the manganese content of the alloy to about 70 per cent.

Silver-Brazing of Stainless-Steel Tubing

G. H. BOHN: 'Silver-Brazing Lap Joints in Stainless-Steel Tubing.'

Welding Jnl., 1956, vol. 35, Sept., pp. 884–9.

The paper presents experimental data and calculations showing that if the lap of a correctly made silver-brazed joint in 18–8 type chromium–nickel stainless steel tubing is made three times the thickness of the tubing the joint will be stronger than the tubing, with regard to resistance to internal pressure, or tensile stresses due to thermal expansion and dead load, or a combination of the two.

Influence of Zinc-Phosphate Coating in Flash-Welding of Alloy Steels

See abstract on p. 216.

CORRIGENDA

Nickel Bulletin, 1956, vol. 29, No. 3, p. 35.

Electroless Plating of Aluminium

For *Metal Finishing*, 1955, vol. 1, No. 12, Dec., pp. 528–537, read *Metal Finishing Jnl.*, 1955, vol. 1, Dec., pp. 528, 537.

ibid., Nos. 8–9, p. 165.

For **Stress-Corrosion Cracking in Nickel-Iron Alloy** read **Stress-Corrosion Cracking in High-Expansion Steel**

First sentence of abstract should read—

'In a high-expansion nickel-chromium-manganese steel tube housing a spring assembly of a low-expansion nickel-iron alloy (Nispan C), stress-corrosion cracking was found to be attributable to . . . '

ibid., Nos. 10–11, p. 184.

Influence of Precipitation Hardening on the Electrical Resistance of Copper-Manganese-Nickel Alloys

For K. L. DAHL read O. DAHL and K. L. DREYER.

Binders bearing the date 195- and suitable for 1956 and 1957 Nickel Bulletins are now available. We shall be pleased to send one free of charge.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

SUBJECT INDEX TO VOLUME 29

The Index comprises a consolidated list of titles of abstracts, compiled from the sectional contents lists of the individual issues.

Within the Sections normally used (**GENERAL, NICKEL, ELECTRODEPOSITION,** etc.), the items are broadly classified in appropriate sub-sections, within which the items are, in most cases, entered in the order of their appearance in the Bulletin. The only exceptions to such order are (1) the grouping of the page numbers of serial items, and of items of very closely related subject and (2) the alphabetical order used in the **GENERAL** Section.

A list of **Trade-Named Materials and Processes** referred to in this volume of the Bulletin appears on p. 233.

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